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Fabrication and characterization of iron nanodiscs with vortex properties and their potential application in magnetic hyperthermia

Franco Álvarez Novoa
Universidad de Santiago de Chile - Centro para el Desarrollo de la Nanociencia y la Nanotecnología, Chile

Rafael Morales Arboleya
Universidad del País Vasco, País Vasco - España

Carolina Redondo Esteban
Universidad del País Vasco, País Vasco - España

Juliano Denardin Casagrande
Universidad de Santiago de Chile - Centro para el Desarrollo de la Nanociencia y la Nanotecnología, Chile

Patricia Díaz Saldívar
Universidad de Santiago de Chile - Centro para el Desarrollo de la Nanociencia y la Nanotecnología, Chile

Magnetic hyperthermia (MH) is a new treatment that uses magnetic fields to generate heat inside the body, making it useful for cancer treatment. Nanodisks (ND) are magnetic nanostructures with unique spin configurations, such as vortex state and large dimensions that preserve zero remanence, preventing aggregation. In addition, they present versatility for the design of magnetic configurations, playing with different sizes and geometries and the significant advantage of growing in multilayers using different types of materials. Our goal was to synthesize multilayer NDs with different sizes, thicknesses and compositions, and analyze their physicochemical, magnetic and biological properties. NDs were manufactured by combining lithography techniques and physical vapor deposition. Three samples were used with the following composition, layer thickness (nm) and diameters: M1: Al 50/ Ti 10/ Fe50 /Ti 10, D = 267 nm; M2: Al 50/ Ti 10/ Fe60 /Ti 5 /Fe 60 / Ti 10, D = 252 nm and M3: Al 50/ Ti 10/ Fe10 /Ti 5 /Fe 10 / Ti 10, D = 653 nm. Then, size and shape (TEM, SEM), composition (EDS), and magnetic properties (VSM, MOKE) were analyzed. The HM tests were performed with the ND resuspended in water to different fields and frequency using the Magnetherm equipment, finally, toxicity tests were performed in HeLa cell cultures. The analysis of morphology and size showed that the 3 samples obtained had a mainly elliptical shape with sizes of M1: 252±3.9, M2: 267±2.7 and M3: 653±12.1 nm. The analysis by EDS confirmed the presence of the different metals that were deposited during evaporation. Of the three samples, M2 was the one with the highest volume of Fe, followed by M1. For magnetic analysis, hysteresis graphs showed the existence of spin-vortex configuration in the analyzed samples, M2 showed higher saturation magnetization value followed by M1 and M3. The analysis of hyperthermia showed that the greatest increase in temperature (ΔT° = 4.9 °C) was with the M1 sample at 618 kHz frequency and 10mT field, although M1 had less Fe content than M2, it was more effective in generating temperature increase, probably because Fe was in monolayer. With respect to the size M1 and M2 were smaller and were more effective in generating the temperature increase. Toxicological analysis showed no toxicity to any of the samples tested. These results show that hyperthermia can be generated with NDs at high frequencies, and that this effect is more evident in samples that have sizes less than 300 nm and presence of Fe in monolayer.

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References

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